Quantifying the Benefits of NEC

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INTRODUCTION

The UK places Network Enabled Capability as one of its highest priorities for future investment in research, acquisition, people and training. A recent Defence White Paper, Delivering Security in a Changing World [1], states that the continued transformation of UK forces is dependent on exploiting the benefits of Network Enabled Capability (NEC). The white paper notes that NEC, through enabling "the ability to respond more quickly and precisely, will act as a force multiplier enabling our forces to achieve the desired effect through a smaller number of more capable assets".

Analysis and experimentation has a key role in helping UK MOD to identify:

- *where will NEC deliver most benefit to defence;*
- *what can be traded off to pay for it;*
- *what changes are required to processes, structures, equipment etc, to deliver the desired transformation.*

Analytical support is being provided in three main ways:

- *"Knowledge-mining" previous work on quantifying the value of information. NEC as a coherent concept is new, but many of its elements have been under analysis for the last few years. These are being brought together to provide a compendium of evidence.*
- *Influencing ongoing studies and experiments to include NEC options in their analysis; e.g. broadening thinking to include people and other non-equipment options.*
- *Auditing key combat and campaign models to establish what aspects of NEC they can model and which aspects need functional improvements in order to be represented. The audit also identifies where data exist and where there are gaps. This activity helps determine the priorities for future model development and for experiments to generate data.*

This paper provides examples of the types of benefits that are being identified through "knowledge-mining" and the methods that have been used in deriving them. It also provides an overview of the model and data audit process that is being undertaken.

[1] Delivering Security in a Changing World: Future Capabilities, July 2004.

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1.0 KNOWLEDGE MINING

NEC is about the coherent integration of sensors, decision-makers and weapon systems along with support capabilities[1]. It is not just about equipment; it is also about exploiting the benefits to be obtained from transformed doctrine and training, and optimised command and control structures[1]. NEC as a coherent concept is new, but many of its elements (equipment, processes, structures, and training) have been under analysis for many years. The knowledge generated was brought together to provide a compendium of evidence, grouped against the themes that describe the characteristics of network-enabled operations. For each of the themes this paper provides a description of its characteristics, a quantified example of its benefit and an overview of the method used to generate the evidence of benefit. The examples highlight that the UK has applied a number of different methods, each of which has delivered a different insight into the benefits of NEC.

Theme 1: Resilient information infrastructure and full information accessibility. This is defined in two parts. The first is "Ensuring information is managed coherently across the battlespace and that the potential for secure and assured connectivity is provided to all battlespace users". The second is "Enabling users to search, manipulate and exchange relevant information of different classifications captured by, or available in, sources internal and external to the battlespace".

An example of benefit from investment in the capability implied by Theme 1 has been identified through the use of campaign modelling. The UK campaign model CLARION[2] was used to explore the balance of investment in anti-armour capability. The analysis illustrated that investment in a networked long-range precision capability (the coherent integration of sensors, information infrastructure, IFPA[3] weapons and decision-makers) reduced the demand for direct fire assets, as they were used more efficiently. The benefits were significantly less if investment was made in enablers or effectors only. The measures of effectiveness used to measure the benefit of NEC were the same measures that would be used to decide whether to invest in a weapon or platform (such as time to achieve campaign objective). This approach allows decision-makers to balance their investment across capabilities including information capabilities, weapons and platforms to achieve the best value for defence.

Theme 2: Shared understanding. This is defined as "Enabling each user to generate an understanding of the battlespace that is appropriate and adequate to their task and consistent with the understanding of other users."

An example of the benefit of shared understanding, in this case facilitated by a shared common picture, was found using a combination of techniques. Analysis of defending airspace under tight Rules of Engagement suggested that the provision of a common operating picture to weapon system operators and the commander controlling authority to engage, plus an appropriate doctrine to take advantage of this, generated massive improvement in the likelihood of correctly identifying an authorised target. The analysis used systems level modelling combined with capability chain assessments that take account of equipment capabilities and decision-making processes. Linear programming was used to identify optimum networked air defence mixes that provided the greatest likelihood of correct identification of targets.

Theme 3: Dynamic collaborative working. This is defined to be "Enabling agile command and control within and between mission groups through the ability to concurrently plan and execute operations in a way that is dynamic, continuous and synchronized."

[2] The CLARION model is an event driven partially stochastic combat model operating at Brigade level and above. CLARION is used primarily in analysing the impact, at the operational level, of changes in organisation or equipment.

[3] Indirect Fire Precision Attack.

Warfighting experiments with digitised[4] forces provided evidence of the benefits of dynamic collaborative working. The experiments used man-in-the-loop collective simulations. It was found that agile command and control delivered significant improvements to the effectiveness of digitised forces in warfighting experiments, compared to forces for which only the timeliness and reliability of information was improved (with no corresponding changes in synchronisation, op tempo or scheme of manoeuvre). By assessing the effectiveness of units, the benefits of agile command and control can be compared with other improvements in capability such as equipment or training enhancements.

Theme 4: Agile Mission Grouping. This is defined to be "Enabling the dynamic creation and configuration of task orientated mission groups that share understanding and that employ and co-ordinate available assets to deliver the desired effect."

An example of the benefit of agile mission grouping was identified by stochastic simulation of kill chains. The analysis illustrated that the ability to prosecute a high priority target through network-enabled fire using any of land, sea and air systems reduced the time taken to prosecute and increased the ability of decision-makers to choose the most suitable asset for prosecuting the target. The main measure of effectiveness was the time taken for each part of the kill chain; this allows decision makers to include agile mission grouping when considering alternative ways of improving the capability to prosecute time sensitive targets.

Theme 5: Effects Synchronisation. This is defined to be "Achieving the desired effects through the synchronization of activities within and between mission groups."

Historical analysis identified an example of the operational benefit of synchronising effects. Evidence from the analysis of 160 land and air campaigns indicates that multiple surprise is important to military success at the campaign level. The analysis showed that if an attacker can keep a defender continually off balance by having a cycle of information gathering, assessment, decision and delivery of effect (i.e. NEC) faster than the defender's, then the chances of success are greatly enhanced. Analysis of 79 amphibious operations demonstrates a link between an attacker having C3 superiority and time to campaign success.

Lessons from the Knowledge Mining Activity

In carrying out the data mining activity, a substantial body of evidence was found to be available from studies, experiments and operations conducted over the past 15 years. The evidence comes from a wide range of sources and had been generated using an equally wide range of methods. It demonstrates that the key to providing an understanding of the benefits of NEC is not the use of one particular method but the application of the full range of analytical techniques, each providing a different insight.

The choice of measures of effectiveness is as important as the method used. In order to address the crucial issue of what can be traded off to pay for NEC, the measures chosen must be the same as those used to assess the benefit of other capability enhancements. This is essential to allow investment in NEC to be compared with other possible investments. The examples given in this paper all use these types of measures and demonstrate how they can be applied in a NEC context.

As expected, more evidence was found relating to the earlier themes such as full information accessibility and shared awareness with much less regarding agile mission grouping or effects synchronisation. This kind of observation is being used to influence the tasking of new analysis and experimentation in the UK. It also raises a concern that some aspects of NEC present new analytical challenges for which current

[4] The digitised force had a regularly updated map display in each vehicle showing all blue vehicle locations and believed red positions from contact reports. Each vehicle was able to use the system to directly call for indirect fire support. The brigade tactical operations centre had the ability to transmit text orders and map overlays to each vehicle.

methods and data might not be suitable. This concern was addressed by the modelling and data audit, which will be described in this paper.

A less expected outcome of the knowledge mining activity was in demonstrating to the analysis community in the UK how existing work provides a basis for understanding NEC. In many cases the originators of the evidence were unaware that their work provided insight into NEC. This leads the way for ongoing and future studies and experiments to consider how they can contribute to the understanding of NEC in the future.

Knowledge Mining Conclusions

This paper uses examples of the evidence collected to illustrate the key features of the knowledge mining activity. This section is intended to provide an overview of the conclusions that can be drawn from the body of evidence as a whole.

The evidence came from a wide range of sources but did produce a coherent picture of the benefits NEC. It shows that investment in network-enabled capability can deliver force-multiplier effects and consequent savings in resource, but only if a coherent approach is taken across all Lines of Development (LoD)[5]. If this is not achieved, then changes to process and to the availability and exploitation of information could lead to degradations in operational capability. This emphasises the need to better understand the priorities for NEC, in terms of which effects are needed by when, so that sufficient effort and emphasis is given to their delivery across all LoD.

2.0 OVERVIEW OF MODEL AND DATA AUDIT PROCESS

Alongside the collection of extant knowledge was an activity to ensure that the right kind of evidence can be produced in the future. Part of this activity is an audit of key combat and campaign models to establish what aspects of NEC can be modelled and which aspects need either functional improvements or additional data to be represented. The aim of the audit is not to find ways of modelling specific NEC issues but to ensure that NEC is considered in the UK's key operational research studies and thus producing more of the type of evidence which was collated in the knowledge mining activity.

The audit assessed a sample of models used for analysis from engagement level to campaign level across domains. The initial part of the audit was to investigate each model's capabilities through structured interviews with expert users. Capability was considered both in terms of the functionality of the model and whether appropriate data is available to support that functionality. The assessment was structured around the NEC themes as used in the knowledge mining activity. For each of the themes a number of aspects were considered, examples are given below:

Resilient information infrastructure. Examples: representation of communications, ability to degrade communications network in different ways, ability to represent network failure or enemy attack.

Information accessibility. Examples: ability to limit information available to different parts of the network, the effects of false information in the network, representation of data fusion, and the effects of information overload and having different levels of trust in information.

Shared understanding. Examples: the representation of decision-making and the influencing factors on it, the level to which situational awareness is represented.

[5] Training, Equipment, Personnel, Information, Doctrine and Concepts, Organisation, Infrastructure, Logistics.

Dynamic collaborative working. Examples: flexibility in the representation of the command structure and processes, the representation of the ability to work dynamically with allies (including the "soft" interoperability factors). The ability to represent agility in C2 such as the dynamic re-tasking of assets.

Agile Mission Grouping. Examples: whether mission groups can be represented and how agile these can be, the effects of team cohesion.

Effects Synchronisation. Examples: the ability to represent the benefits of achieving effects in a short space of time such as shock, surprise and momentum.

Engaging with the modelling community for this audit had two-way benefits. The interviews not only allowed an assessment to be made of model capability but also gave the model experts an interpretation of what the kind of aspects their model would need to consider to represent NEC.

It is recognised that each model needs an appropriate representation of NEC for its use and that this is specific to each model. Therefore interviews were conducted with study leaders to gain an understanding of how the models are used currently and possible future uses. This was used as a guide to identify where gaps in functionality or data existed and which gaps were most severe.

One finding of the audit that was anticipated was that the UK's modelling capability is deficient in modelling the human elements of NEC. This deficiency is caused by an underlying lack of understanding of human factors at an aggregated level that can be represented in combat models. In cases where the understanding is in place, the supporting data is often unavailable. A more positive result was that whilst no model had a good representation of all of the themes, there were models which represented most of the non-human elements of the themes well. The exception was "synchronisation of effects" which was not represented well by any model, this stems from a lack of understanding in this complex area.

Whilst deficiencies in modelling of human behaviour will take a great deal of work to improve, there were other areas identified which could be improved more easily, such as the ability to represent network degradation or attacks on the network and the representation of false or imperfect information. These aspects are currently either poorly represented or not represented at all in most models.

3.0 OUTLINE OF NEXT STEPS

The activities described in this paper are initial steps of a process of quantifying the benefits of NEC. The process is intended to help inform MoD on three key NEC questions that need to be addressed:

- Where does NEC deliver most benefit to defence?
- What can be traded off to pay for it?
- What changes are required to processes, structures, equipment etc., to deliver the desired transformation?

The knowledge mining activity will continue bringing together new evidence as it emerges and searching further for more existing evidence from both UK and Allied sources. The results of the initial activity are being used to influence the tasking of analysis and experimentation in the UK.

The results of the modelling and data audit will be used to influence model development activity. It will also be used to influence the tasking of experimentation to provide the data necessary for an improved representation of NEC in the UK's combat models.

Quantifying the Benefits of NEC

Georgia Court

Outline

- What is Network Enabled Capability?
  - Definition
  - The role of analysis and experimentation
- Evidence of the Benefits of NEC
  - Examples of the evidence collected
  - Methods used
  - Lessons learnt
- NEC Models Audit
- Next Steps

NEC is….

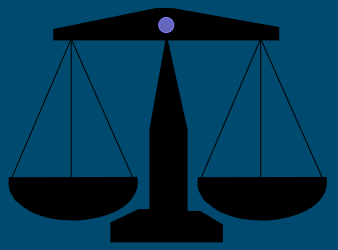
- The coherent integration of sensors, decision-makers and weapon systems along with support capabilities
  - to bring to bear the right military capabilities at the right time to achieve the desired military effect
  - this ability to respond more quickly and precisely will act as a force multiplier enabling our forces to achieve the desired effect through a smaller number of more capable assets
- More than equipment; also transformed doctrine and training and optimised command and control structures

* Source: Defence White Paper, *Delivering Security in a Changing World*, July 2004

NEC Core Themes

Resilient Information Infrastructure	Ensuring information resources can be managed and that secure and assured access is provided to all battlespace users with the flexibility to meet the needs of Agile Mission Groups
Full Information Accessibility	Enabling users to search, manipulate and exchange relevant information of different classifications (respecting security constraints) captured by, or available in, all sources internal and external to the battlespace.
Shared Understanding	Providing Shared Situational Awareness and Command Intent (the intentions of friendly forces, and the potential courses of action) amongst collaborating elements in the battlespace.
Dynamic Collaborative Interworking	Enabling agile command and control of Agile Mission Groups through the ability of all elements to concurrently plan and execute operations in a way that is dynamic, continuous and synchronized.
Agile Mission Groupings	Enabling the dynamic creation and configuration of task orientated Mission Groups that share awareness and that employ and co-ordinate available assets to deliver the desired effect.
Effects Synchronization	Achieving overwhelming effect through the synchronization of activities within and between Agile Mission Groups, and with other sensors, effectors and decision makers.

Analysis Support to NEC

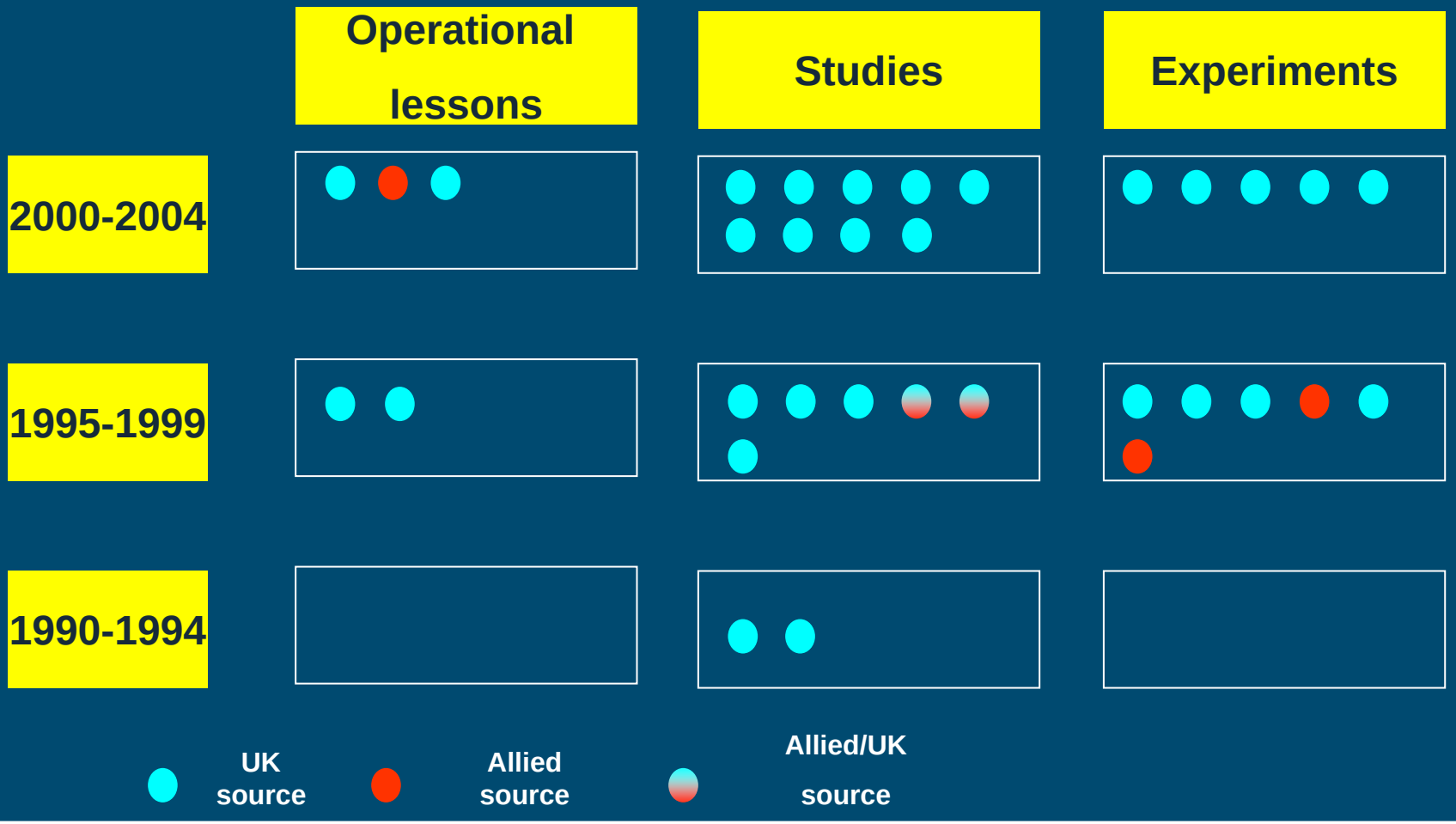


- Analysis and experimentation has a role in helping UK MoD to identify:
  - Where NEC will deliver most value to defence
  - What can be traded off to pay for it
  - What changes are required to deliver the required transformation
- Analysis support is being provided in 3 ways;
  - Knowledge mining existing evidence of the benefits of NEC
  - Influencing ongoing studies and experiments to include NEC
  - Auditing key combat/campaign models

Knowledge Mining

- The ideas within NEC are not new - work over past decade or so has considered many of them
- “Knowledge mining” previous work to bring together existing evidence which quantifies potential benefits and risks:
  - Studies
  - UK and Allied Experimentation
  - Evidence from operations

Knowledge Mining: Sources

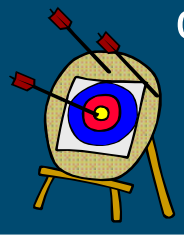


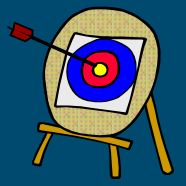
Examples by NEC Theme

- Resilient information infrastructure and Full information accessibility
  - Investment in a networked long-range precision capability (the coherent integration of sensors, information infrastructure, precision attack weapons and decision-makers) reduced the need for direct fire assets.
  - Used campaign-level modelling to consider the same measures of effectiveness as have traditionally been used to decide whether to invest in a weapon or platform.

Examples by NEC Theme

- Shared understanding
  - In defending air space under tight rules of engagement, a common picture for weapon system operators and the commander, plus the appropriate doctrine to take advantage of this generated a large improvement in the likelihood of correctly identifying an authorised target.
  - A combination of methods was used to produce this evidence, systems level modelling combined with capability chain assessments. Linear programming was used to identify the optimum networked air defence mixes.





Examples by NEC Theme

- Dynamic collaborative working
  - Agile C2 delivered significant improvements to the effectiveness of digitised forces in warfighting experiments, compared with forces for which only the timeliness and reliability of information was improved.
  - The experiments used man-in-the-loop collective simulations.
  - By assessing unit effectiveness the benefits of agile C2 can be compared with other improvements such as equipment or training enhancements.

Examples by NEC Theme

- Agile mission grouping
  - The ability to prosecute a high priority target through network-enabled fire using any of land, sea and air systems reduced the kill chain completion time.
  - Stochastic simulation of kill chains was used to consider the time taken to prosecute a target.

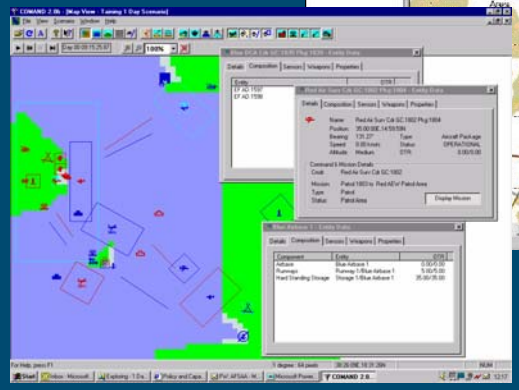
Examples by NEC Theme

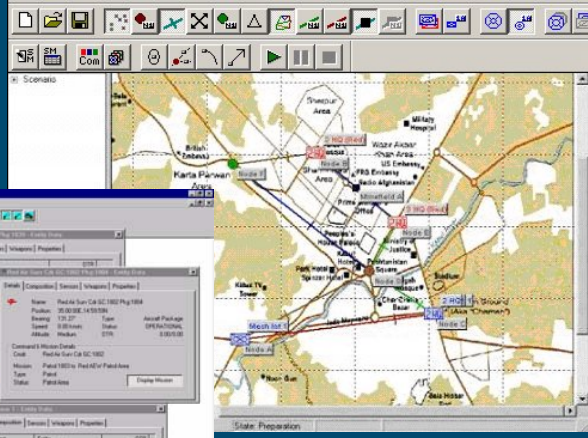
- Effects synchronisation
  - Multiple surprise is crucial to military success at the campaign level. If an attacker can keep a defender continually off balance by getting inside his decision cycle time, then the chances of success are greatly enhanced.
  - This evidence was generated from historical analysis of 160 land and air campaigns.

Lessons from Knowledge Mining

- Evidence comes from a wide range of methods.
- Choice of measures of effectiveness is important - need to balance investment in NEC with other possible investments.
- Available evidence was not spread evenly over themes.

NEC Audit of Key Models





- Purpose is to ensure that NEC is considered in the UK's key operational research studies.
- Aim is to identify which aspects of NEC can be analysed, both in terms of model functionality and the data to support it.
- The output will inform future model development and NEC experiments.

The Audit

- The models to be audited: those considered to be “key”, from engagement to campaign level, across operational domains.
- The audit will use structured interviews with model experts and will be based around the NEC themes.
- The level of representation needs to be appropriate for the model’s use. An understanding of each model’s current and future use will be gained in order to assess the severity of any gaps in functionality or data.

Next Steps

- Knowledge mining continues to identify further evidence from existing work.
- The output from the knowledge mining to date is influencing the design of planned and ongoing studies and experiments.
- On completion of the model audit, the outcome will be used to influence model development and NEC experimentation.

Questions?